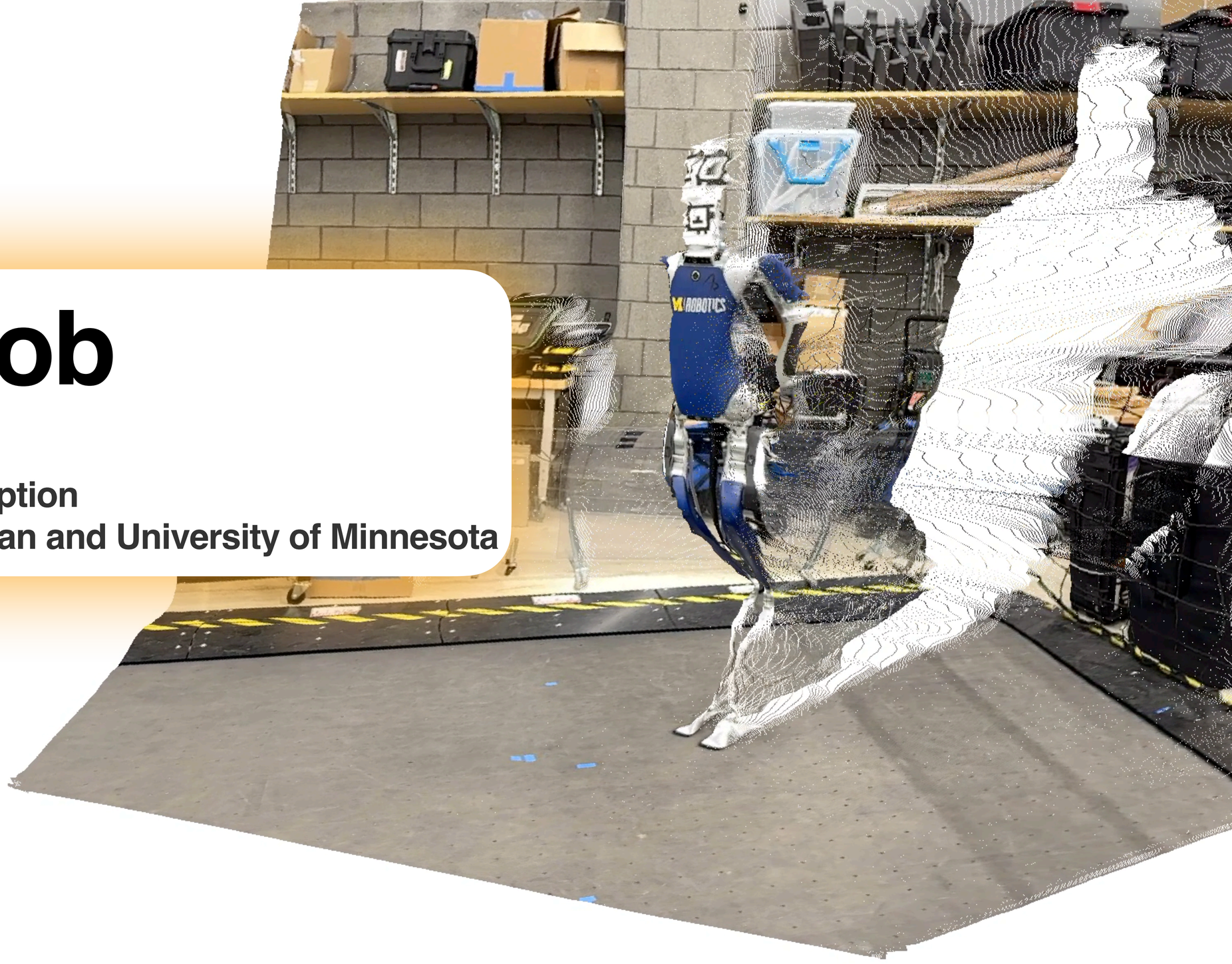
DeepRob

Discussion 7
Prelude to 3D Perception
University of Michigan and University of Minnesota



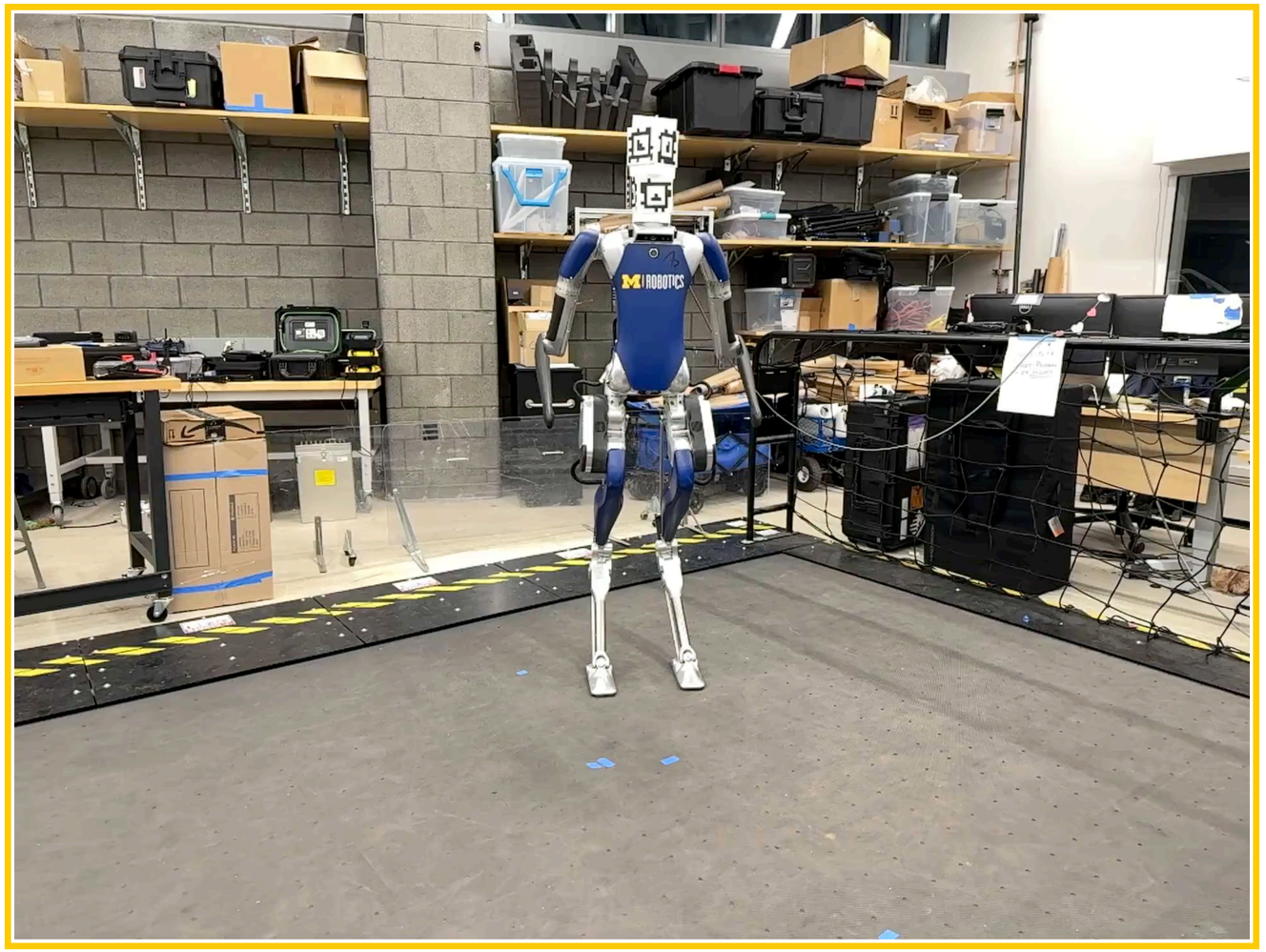
Next Week: 3D Perception

- Seminar 1: RGB-D Architectures
  1. PoseCNN: A Convolutional Neural Network for 6D Object Pose Estimation in Cluttered Scenes, Xiang et al., 2018
  2. A Unified Framework for Multi-View Multi-Class Object Pose Estimation, Li et al., 2018
  3. PVN3D: A Deep Point-Wise 3D Keypoints Voting Network for 6DoF Pose Estimation, He et al., 2020
  4. Learning RGB-D Feature Embeddings for Unseen Object Instance Segmentation, Li et al., 2021
- Seminar 2: Point Cloud Processing
  1. PointNet: Deep Learning on Point Sets for 3D Classification and Segmentation, Qi et al., 2017
  2. PointNet++: Deep Hierarchical Feature Learning on Point Sets in a Metric Space, Qi et al., 2017
  3. PointFusion: Deep Sensor Fusion for 3D Bounding Box Estimation, Xu et al., 2018
  4. DenseFusion: 6D Object Pose Estimation by Iterative Dense Fusion, Wang et al., 2019

From 2D to 3D: Perception in a new dimension

“Video of WMT-TV switching from black and white to color broadcast”: source from CBS 2 Iowa

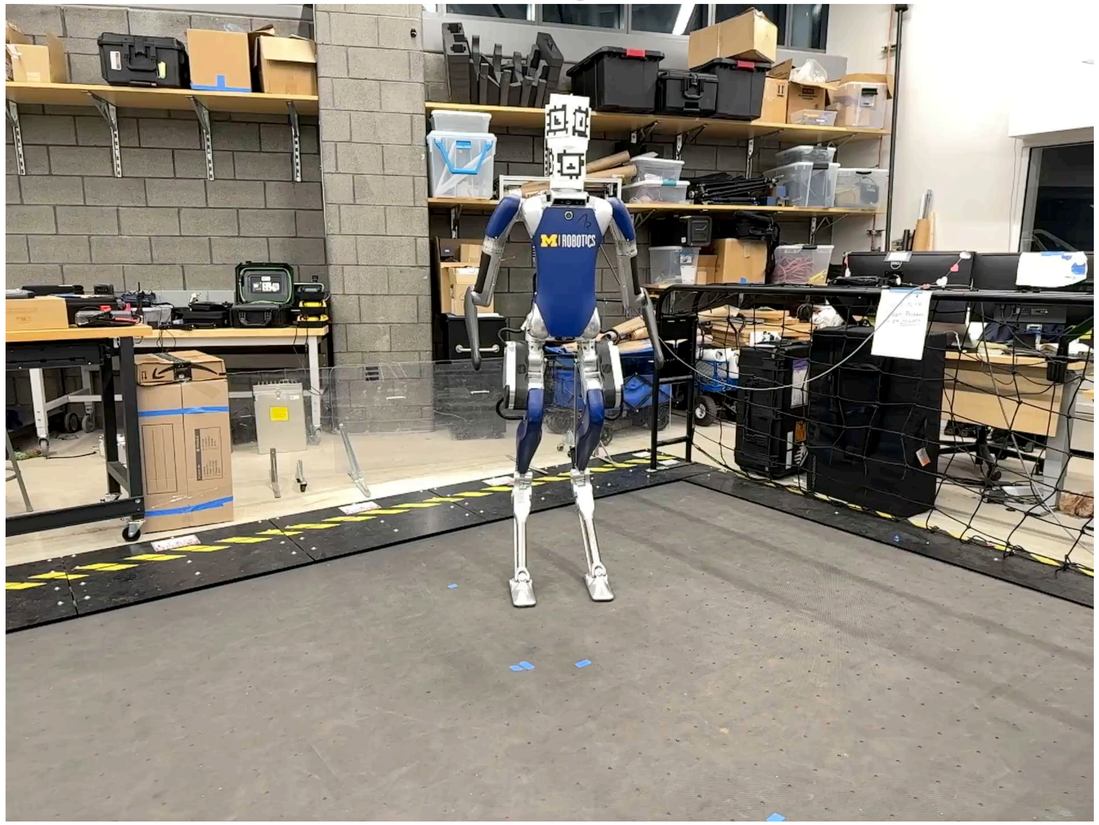
From 2D to 3D: Perception in a new dimension



Data courtesy of Anthony Opipari, Liz Olson, Grant Gibson, and Arden Knoll

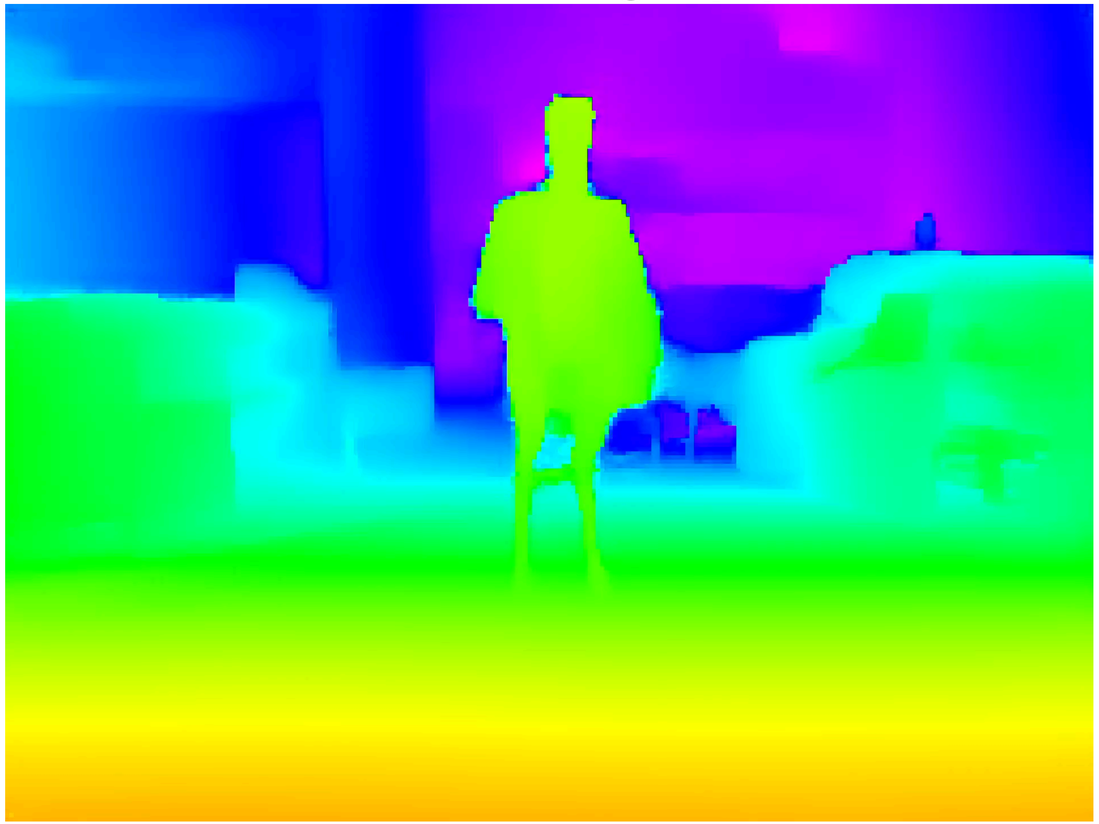
RGB-D Images

Color Image (RGB)



3 x 1920 x 1440

Depth Image (D)

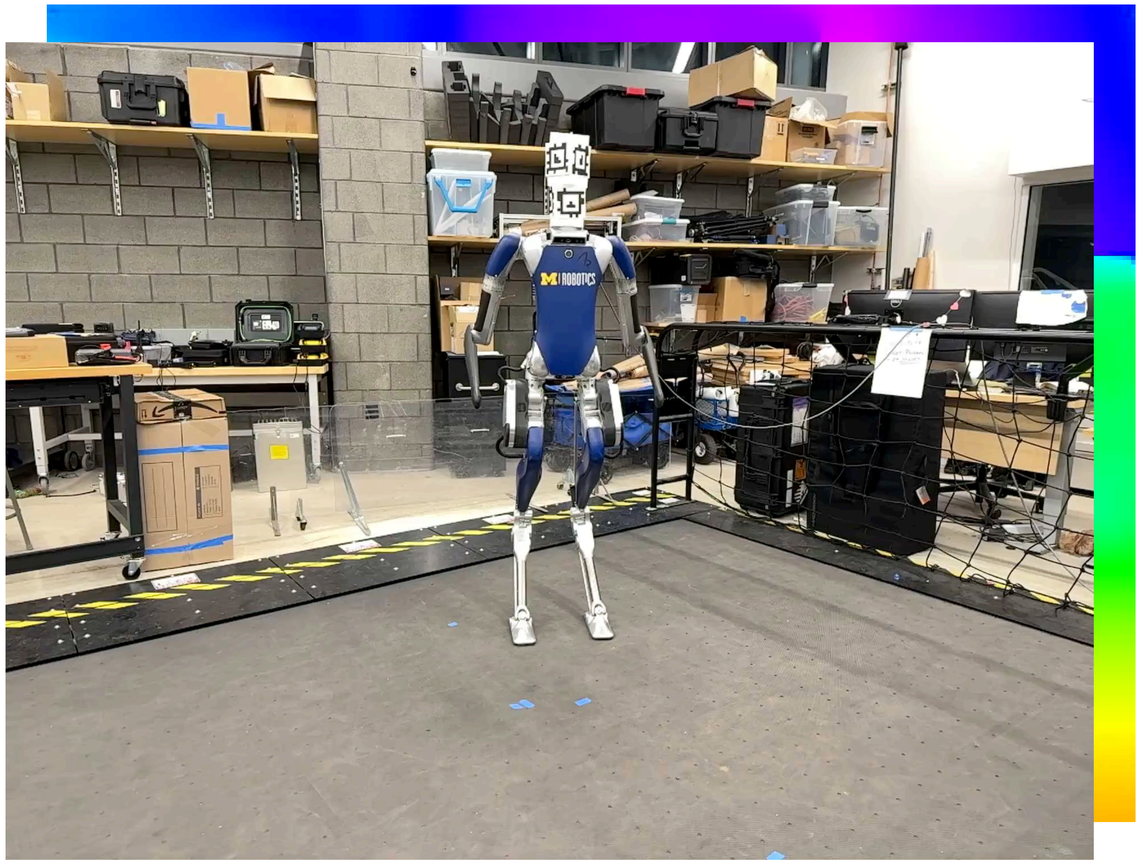


1 x 1920 x 1440

Data courtesy of Anthony Opipari, Liz Olson, Grant Gibson, and Arden Knoll

RGB-D Images

RGB-D Image



4 x 1920 x 1440

Deep Network

- **2D Object Detection**
- **2D Semantic Segmentation**
- **2D Instance Segmentation**
- **3D Object Detection**
- **3D Depth completion**
- **3D Instance Segmentation**
- **3D Reconstruction**
- **3D Semantic Scene Completion**
- **6DoF Pose estimation**

Data courtesy of Anthony Opipari, Liz Olson, Grant Gibson, and Arden Knoll

RGB-D Sensors

Stereo cameras

1. Capture multiple images from displaced cameras
2. Find feature correspondences across images
3. Use known camera displacement to estimate depth image

Structured light sensors

1. Project known Infrared (IR) light pattern onto scene
2. Capture image in IR frequency
3. Use known pattern to compute depth image

Time of flight sensors

1. Produce infrared laser toward scene
2. Record time taken between transmission and response
3. Use known speed of light source to estimate depth image

Aside: Event Cameras

Consider time as the 3rd dimension

- Only record information as change occurs over time
- Better dynamic range than color cameras

CVPR 2021 Workshop on Event-based Vision

Point Clouds

Point Cloud
A discrete collection of 3D points
Representation of 3D geometry
N x 3

Sources

Depth images with calibrated camera transformed into point clouds by projecting pixels along ray to depth

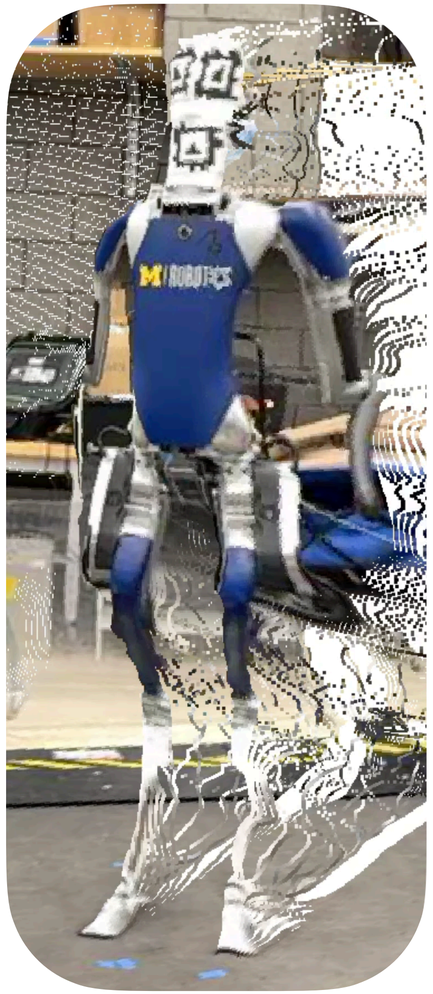
Object geometries (vertices, faces) transformed by sampling on surface

Data courtesy of Anthony Opipari, Liz Olson, Grant Gibson, and Arden Knoll

Recognition

Input
Point cloud: N x 3

Output
Categorical label for object in point cloud

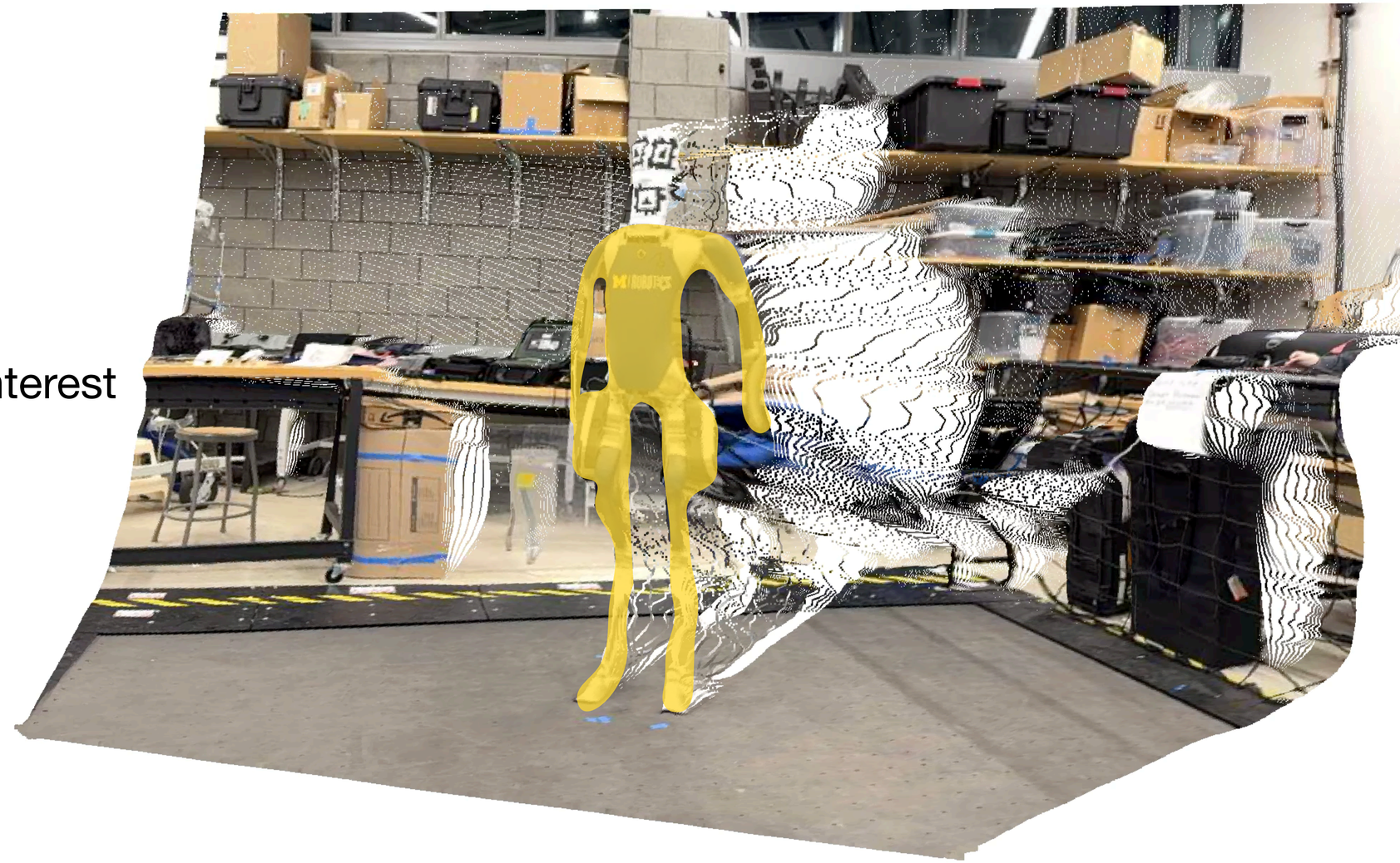


“Digit Robot”

Segmentation

Input
Point cloud: N x 3

Output
Categorical label for each point corresponding to an object of interest
N x (C+1)

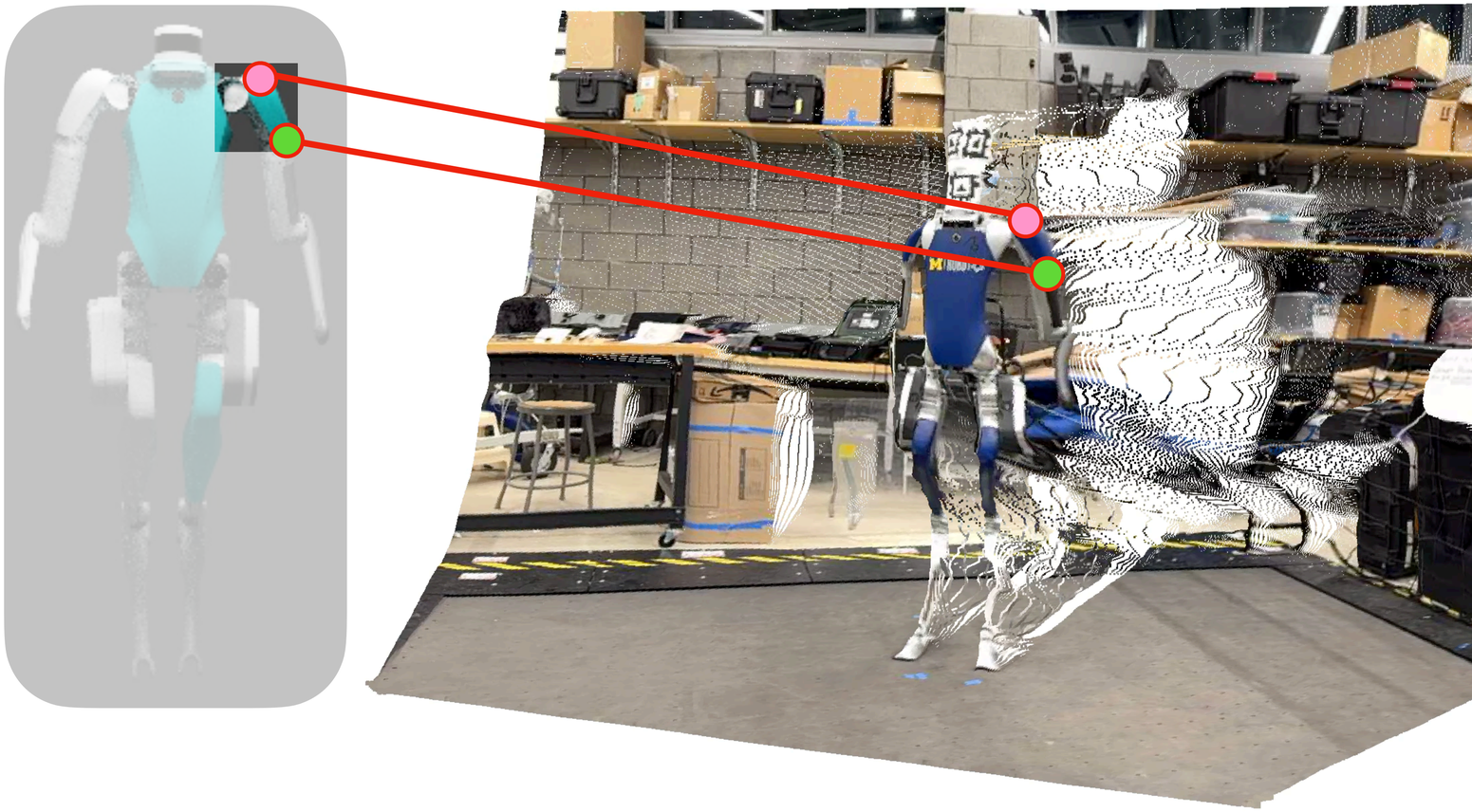


Registration

Input
Object geometry (vertices, faces)
Point cloud: N x 3

Output
Rigid body transformation for geometry to point cloud frame

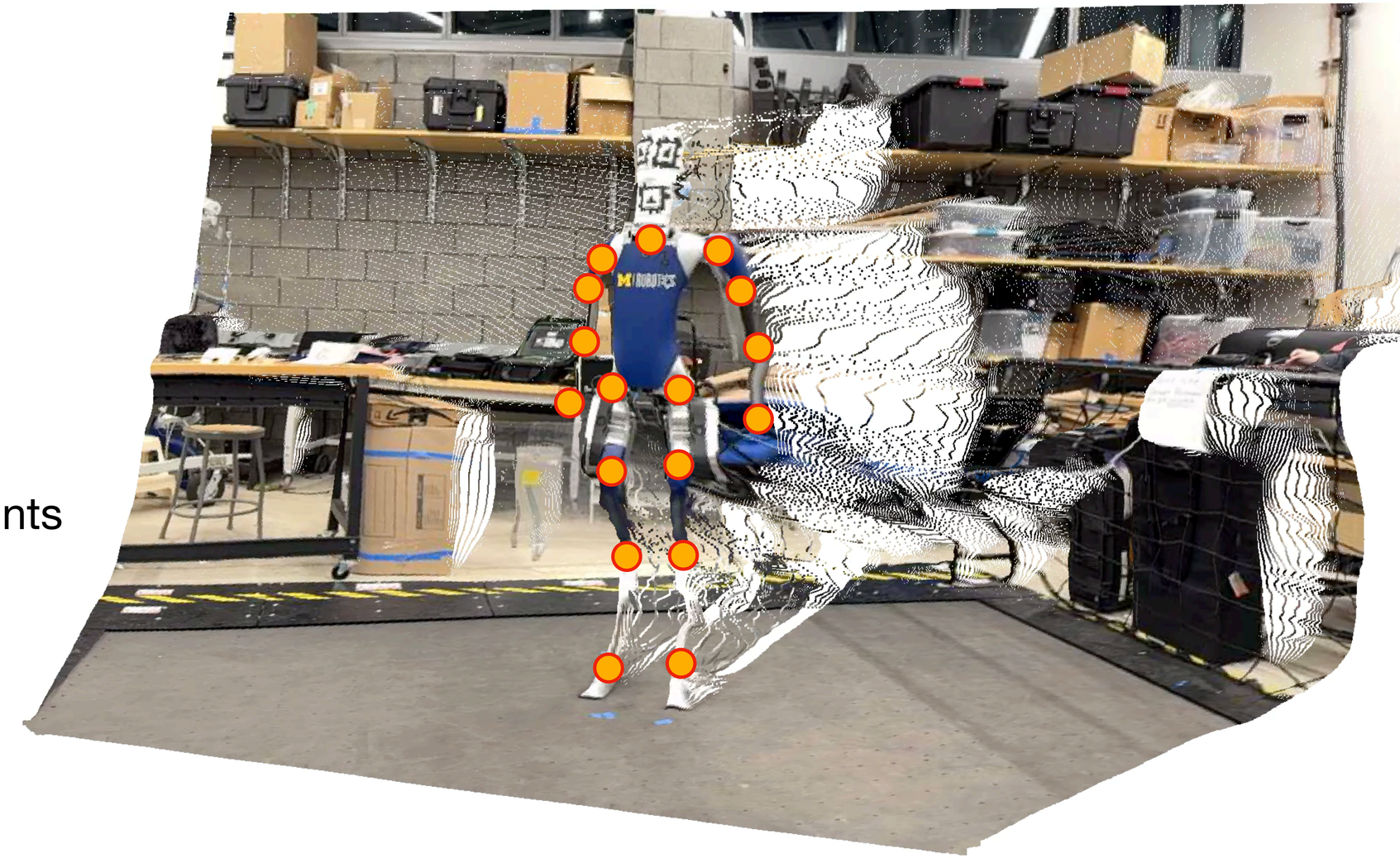
Pairwise point correspondences between geometry and point cloud



Keypoint Detection

Input
Point Cloud: N x 3

Output
3D Keypoint locations: 17 x 3
Corresponding to object link/joints



Data courtesy of Anthony Opipari, Liz Olson, Grant Gibson, and Arden Knoll

Surface Reconstruction

Photogrammetry

Input Images

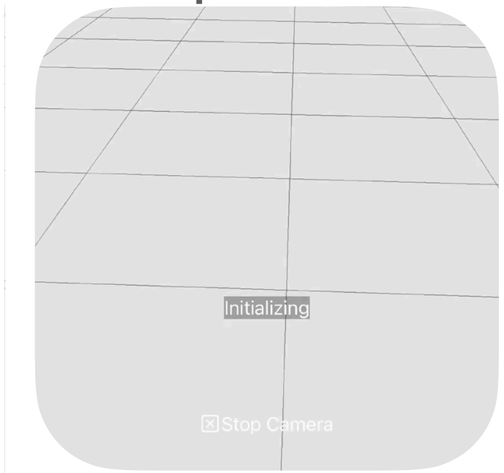
Output Geometry

Data courtesy of Anthony Opipari, Stanley Lewis

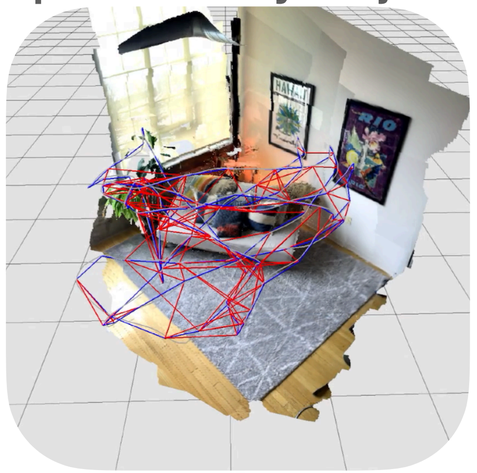
Object model from YCB Object and Model Set, Calli et al.

Mapping

Input Video



Output Geometry+Trajectory



Data courtesy of Anthony Opipari using RTAB-Map

Data courtesy of Anthony Opipari using RTAB-Map

3D Perception Resources

-  Point Cloud Library (pcl)
  - Large open source project for point cloud processing
  - Integrated with ROS
-  PyTorch3D
  - A Python library for deep learning with 3D data
  - Builds on top of PyTorch

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